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Book of Abstracts
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Kellie Ann Beall, Editor

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National Institute of Standards and Technology
Raymond G. Kammer, *Director*

Using Bench Scale Fire Measurements in Large Scale Simulations

Kevin McGrattan, Anthony Hamins and Linda Blevins
National Institute for Standards and Technology
Gaithersburg, Maryland, USA

A program is underway at NIST to develop a numerical field model, referred to as the Industrial Fire Simulator (IFS), to simulate large scale fire phenomena. Because the model is intended to simulate fire flows within buildings whose volumes are on the order of tens of thousands of cubic meters, it is not practical to implement detailed submodels of phenomena occurring at length scales less than a few tens of centimeters, including combustion, boundary layer effects, convective heat transfer, and fire suppression. Instead, bench scale measurement techniques are being developed that will provide the necessary information that will represent these phenomena in the simulations.

This type of effort has been undertaken before to provide zone models with empirical characterizations of various fire-related devices, such as sprinklers. Although much of this work is still applicable in field model calculations, the extra level of detail afforded by the increased spatial resolution requires additional measurements. For example, the total heat release rate as a function of time for a fire consuming a given fuel array would be sufficient information for a zone model to make a predication of an average upper layer temperature. However, if one is attempting to predict the growth of the fire from a point ignition source, more information is required, such as the thermal properties of the fuel and its heat release rate per unit volume.

The part of the model requiring the least amount of empirical information is the hydrodynamic calculation. It is based on large eddy simulation (LES) techniques to solve the differential equations that govern the transport of smoke and hot gases from a fire [1, 2]. Although transport is a very important part of the model, most of the uncertainty in its predictions and the need for empirical information is due to the calculation of the growth and suppression of the fire. In the model, the fire is represented by Lagrangian particles, referred to as thermal elements, that release heat as they are transported by the thermally-induced motion. Since the fluid motion determines where the heat is actually released, and the heat release determines the motion, the large scale features of the coupling between the fire and the smoke transport are retained. The heat release rate per unit mass of burning fuel is determined from experiment. The spread of the fire through the fuel array is predicted by the model based on measurements of the thermal properties of the objects and the thermal radiation from the fire. Smoke transport is simulated by tracking the thermal elements after the fuel burnout is completed. A specified percentage of the fuel consumed is assumed to be converted to smoke particulate. Thus, a knowledge of the spatial distribution of the thermal elements is equivalent to a specification of the smoke particulate density at any instant of time.

Computing the effects of a sprinkler spray requires measurements of both the thermal response of the device itself, plus the size and initial trajectory of the water droplets. The temperature of the sensing element of an automatic sprinkler is estimated in the IFS model using the analysis of Heskestad and Bill [3]. The activation of a sprinkler is governed by two parameters, one of which is a measure of the sprinkler link's sensitivity to heat, the second a measure of the conductive losses away from the link. A small wind tunnel, or plunge oven, is used to determine both of these parameters. Once a sprinkler has activated, the sizes, temperatures and trajectories of a representative sample of the water droplets are computed. The sampling of droplets has been referred to as the "superdrop" concept [4]. In the IFS calculations that will be presented, typically five to ten thousand droplets from each active sprinkler interact with the gas at any given time. This number of droplets ensures that a sufficient distribution of the water is obtained. The NIST experimental effort is being directed towards characterizing the initial conditions for the droplet spray based on measurements of droplet sizes and density patterns of sprays not subjected to a fire plume. Ultimately, a database will be assembled containing the necessary information to compute the effect of the sprinkler spray on a fire. These measurements are not easy to make because of the large amount of water flowing from a typical industrial scale sprinkler.

Extinguishment of the fire is the single most difficult component of the numerical model. To date, most of the work in this area has been performed at Factory Mutual. An important paper on the subject is by Yu *et al.* [5]. Their analysis yields an expression for the total heat release rate from a rack storage fire after sprinkler activation. Unfortunately, this analysis is based on global water fluxes and burning rates. The IFS model requires more detail about the burning rate as a function of the local water flux. Until better models can be developed, the present extinguishment model consists of an empirical rule that decreases the local heat release rate as more water is applied. This estimate of the fire suppression depends strongly on the make up of the commodity. Much of the NIST bench scale experimental effort is presently being directed towards improving this part of the model.

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